APPENDIX 8-11

RESERVOIR CONFIGURATION TECHNICAL MEMORANDUM

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BLACK & VEATCH

TECHNICAL MEMORANDUM

South Florida Water Management District
EAA Reservoir A-1
Work Order No. 2

B&V Project 140502
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Task 16.23 Reservoir Configuration Technical Memorandum

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1. OBJECTIVE

The purpose of EAA A-1 reservoir is to capture Everglades Agricultural Area (EAA) basin runoff and releases from Lake Okeechobee. The facilities should be designed to improve the timing of environmental water supply deliveries to Stormwater Treatment Area (STA) 3/4 and the Water Conservation Areas (WCAs), reduce Lake Okeechobee regulatory releases to the estuaries, supplement agricultural irrigation demands, and increase flood protection within the EAA. (Hornung et al.)

The construction of the A-1 Reservoir should take full advantage of as much of the acreage available for its use to maximize the amount of storage and minimize the cost per acre-foot while providing necessary clearances along the perimeter of the embankment.

The overall objective of the Reservoir Configuration Technical Memorandum is to summarize the recommended reservoir configuration resulting from:

- Space requirements for construction of the reservoir embankment
- Embankment configuration
- Slope protection
- Seepage collection canal
- Water conveyance structures and pump stations
- Downstream toe drainage
- Space requirements to address other constraints encountered along the site perimeter

For purposes of this technical memorandum, all alternatives are based on a 12 ft. water depth. Additionally, where embankment height or quantities are referenced, numbers are derived from embankment heights resulting from regular wave analysis, and excluding irregular waves. This could result in a minimal amount of overtopping for extreme design storm events. This will be discussed in further detail in the BODR.

This technical memorandum is supplemented by a parallel technical memorandum prepared under Work Order 7 which addressed the costs associated with variable reservoir water depths and an optional configuration that includes additional area outside of the established A-1 tract.

It is anticipated that the perimeter will consist of the embankment, a trench area, a seepage canal, and an access area between the canal and the property line. The exception to this may be along the STA 3/4 supply canal for reasons identified herein.

2. AVAILABLE LAND

The Central and South Florida Comprehensive Review Study (Restudy), conducted by the U.S. Army Corps of Engineers (Corps) in 1999, recommended a storage capacity of 360,000 acre-ft for Parcel A (see Figure 1).

As part of the Acceler8 program currently underway, the South Florida Water Management District (District) plans to construct a portion of the EAA Project reservoir in the eastern section of Parcel A (See Figure 2, Sub-Parcel A-1), an area of about 16,000 acres, and has tasked Black & Veatch (Consultant) to design a such reservoir with an originally intended storage capacity of approximately 190,000 acre-ft. Sub-parcel A-2 would be designed at a later date with the remaining storage capacity. Contingent upon the actual reservoir's final footprint, a water depth of 12 feet, and existing constraints, the design storage capacity for reservoir A-1 would be approximately 190,000 acre-ft.

3. PARCEL A-1 BOUNDARY CONSTRAINTS

The limits of the land acquired by the District for the proposed EAA Reservoir A-1 site are shown on Figure 2. Existing conditions and requests made by various agencies have generated constraints on all four site boundaries, and the requirements of adjoining properties will be a determining factor in the final configuration of the reservoir.

3.1 East Boundary

The east boundary at Parcel A-1 is formed by the Highway 27 right-of-way along its entire length. Highway 27 in turn is bordered along its entire eastern right-of-way by the North New River Canal which parallels the highway along the entire length at Parcel A-1.

The Department of Transportation (DOT) requires that the ground water table not be allowed to rise into the highway sub-grade. Therefore, seepage control measures will be implemented to guard against this potential.

Additionally, expansion of Highway 27 to a four lane divided highway was considered. Due to the proximity of the North New River Canal adjacent to its eastern right-of-way, any expansion of right-of-way would need to be to the west and further setback required. However, the DOT has since notified the District that it will not be requesting any additional setback.

3.2 North Boundary

The District initially advised the Consultant of the existence of 3 rows of palm trees bordering the entire North boundary of the site and that measures should be considered in the final reservoir configuration design to mitigate damage to the palm trees both during and after construction. The District's Project Manager has since advised that the palm trees should not be a determining factor in the reservoir's configuration.

The Fish and Wildlife Service, in their Planning Aid Letter, has requested a 500-acre wildlife buffer zone be created on the North and West boundaries of Parcel A, consisting of a short-hydroperiod wetland with an associated upland. The purpose of a habitat buffer would be to increase the spatial extent of short-hydroperiod wetlands and terrestrial habitat, and partially compensate for wetland and upland habitat that will be impacted by the construction of the reservoir. The goal is to improve native habitat and biological diversity for the EAA Project reservoir, to provide improved ecological stability and resiliency at local, regional, and system-wide scales. It is anticipated that only wetlands within the A-1 parcel will need to be replaced in the first phase of construction. Wetlands in the A-1 area currently occupy about 188 acres.

Agricultural fields adjacent to the north boundary also constitute a constraint that could impact the reservoir's configuration. The Corps has indicated that seepage control measures should be implemented to limit the off site water table rise to 0.5 feet. However, the Corps is currently evaluating off-site impacts and a new groundwater table rise target value will be established at a later date.

3.3 West Boundary

3.3.1 West Boundary, North of Future A-2 Reservoir

Fish and Wildlife Service requests, and agricultural field constraints addressed in Paragraph 3.2, apply to this 0.7 mile section of the Western boundary.

3.3.2 West Boundary - East of Future A-2 Reservoir

The long term plan is to construct the A-2 reservoir in order to meet the intended 360,000 acre-ft goal. Until A-2 is constructed, the District may allow the continuation of farming west of the A-1 site. Some mitigation of wetlands may be required along the western boundary to offset existing wetlands in the A-1 parcel. The constraints related to the agricultural fields discussed in Paragraph 3.2, still apply.

3.3.3 West Boundary – East of Holey Land Wildlife Management Area, North of Supply Canal

The A-1 Reservoir site is separated from the Holey Land by the STA Supply Canal. The supply canal has an embankment and a seepage canal which parallels on all the reservoir side of the canal.

The Holey Land Wildlife Management Area is periodically allowed to dry up for environmental reasons, during which time hunting is permitted on the property. It is expected that a significant rise in the water table during such periods will be undesirable. Additional information is needed regarding the timing of wet and dry periods in order to assess the possible impact on the area resulting from the EAA Reservoir A-1 project.

3.4 South Boundary

The supply canal and STA 3/4 provide constraints along the southern boundary. The supply canal operates at an average water surface elevation of approximately 13.6. Seepage through the northern embankment is collected in a seepage canal and returned to the supply canal by a set of seepage pumps in the G-370 and G-372 pump stations. Operating levels in the EAA Reservoir A-1 will vary from elevation 8.6 to 20.6. At times when the water surface in the reservoir is higher than elevation 13.6, the supply canal can serve as a seepage collection component. At times when the reservoir water surface is lower than elevation 15, seepage could be reversed, into the reservoir. For either condition, there does not appear to be a need to retain the existing seepage canal. There have also been discussions indicating uncontrolled seepage towards STA 3/4 may be acceptable. Seepage quantities will be determined by modeling, but it is not expected that STA 3/4 will require seepage control measures.

4. MODELING

The data collected from the test cell study are being used to determine the hydraulic conductivity of the aquifer layers beneath the test cell site using the two-dimensional groundwater model SEEP/W. The resulting conductivity values will then be applied to a three-dimensional model of a much larger region encompassing the EAA Reservoir A-1 and surrounding agricultural and stormwater treatment areas. The MODFLOW model will be used to evaluate the amount of seepage that will bypass the perimeter seepage collection canal and determine the rise in groundwater levels in these areas. Both two-dimensional and three-dimensional modeling will then be performed to evaluate the effectiveness of several seepage control alternatives to minimize seepage from the EAA Reservoir A-1 and minimize any adverse effects on surrounding areas. Different widths of buffer zones, dimensions of seepage canals, and combinations thereof, will be evaluated to determine the optimum configuration alternative.

Model runs conducted to date indicate the following conclusions:

- The proximity of the seepage canal to the embankment has little impact on the amount of seepage from the reservoir
- The proximity of the seepage canal to the embankment has an impact on the amount of seepage that is recoverable. The further the canal is from the embankment, the less seepage can be recovered
- The canal depth does have an impact on the amount of seepage from the reservoir. A deeper canal results in higher seepage rates, but also improves recoverability

5. OPTIONAL PERIMETER CROSS SECTIONS

Based on existing conditions and constraints identified, two cross section options (A and B) for each of the four boundaries have been developed. Option A maximizes the reservoir footprint and ignores some of the constraints; Option B takes into consideration the constraints identified and reflects the impact they have on the configuration of the reservoir.

5.1 East Boundary

See Figures 2 and 3.

The perimeter configuration options for the east boundary are shown in Figure 3.

Option A includes an embankment dimensioned in accordance with an earthen embankment with a 14 foot crest height width and a 3:1 interior and exterior side slopes as described in the Embankment TM. The profile includes a 150 ft. bench between the toe of the embankment and the seepage canal. The width of the seepage canal would be based on the recommended depth and width for optional seepage capture. A 60 foot space has been provided between the seepage canal and the property line to allow access.

Option B is essentially the same as Option A, except that it allows for additional space between the seepage canal and the property line to accommodate any setbacks required by DOT (to be determined). From the standpoint of controlling seepage into the highway sub-base, it is desirable to locate the seepage canal as close as possible to the highway so that it can have maximum impact on draw-down at shallow seepage in the area. However, since the DOT decision to not request additional setback, this alternative is no longer applicable.

5.1.1 Option A

Advantages include:

- Adequate space provided for access on both sides of the seepage canal and along the embankment toe.
- Reservoir storage capacity maximized. 440 acre-ft more than Option B.

No disadvantages have been identified.

5.1.2 Option B

Advantages include:

- It will conform to DOT requirements.
- Potential for increased access space between the seepage canal and the property line.

The primary disadvantage is that an increase in the perimeter space will result in a subsequent reduction of storage volume, about 10 acre-feet for every 1 foot of encroachment.

The results obtained from the SEEP/W and MODFLOW models shall be considered to determine the optimum distances between the embankment, seepage canal and HWY 27, as well as the cross-section of the seepage canal.

5.2 North Boundary

See Figures 2 and 4.

The perimeter configuration options for the north boundary are shown on Figure 4. These configurations would also apply to the west boundary north of the future A-2 Reservoir.

Option A is similar to that shown for the east boundary. The primary difference is that the bench between the canal and the property line has been increased to 150 feet to allow installation of an access road and to allow sufficient turn around space for future construction access to the A-2 Reservoir, and the exterior bench is increased from 150 feet to 200 feet to provide some areas for wetlands.

Option B is similar to Option A, except that it expands the bench between the embankment toe and the canal, to 350 feet. This would allow a 50 foot dry bench for embankment inspection and a larger 300 foot width to accommodate the wetlands as requested by Fish and Wildlife Services.

5.2.1 Option A

Advantages include:

- Reservoir storage capacity maximized. 775 acre-ft more than Option B.

Disadvantages include:

- A modification to the Fish and Wildlife Service’s requests. However, additional exterior bench provided along the eastern border can contribute to meeting the request.
- Closer to agricultural land; could increase possibility of crop damages from rising ground water.

5.2.2 Option B

Advantages include:

- Embankment volume is reduced by 25,000 cu. yds.
- Incorporates Fish and Wild life Service’s requests; compensates for lost/impacted wetlands by providing 56 acres more than Option A (excluding eastern boundary’s contribution to wetland area)
- Embankment is further away from agricultural land
- Compensates for lost/impacted wetlands

Disadvantages include:

- Reservoir storage capacity is reduced from optimal by 775 acre-ft.

5.3 West Boundary – North of A-2 Expansion

See Figures 2 and 4.

These options are identical to those for the North boundary.

5.3.1 Option A

Advantages include:

- Reservoir storage capacity maximized. 775 acre-ft more than Option B.

Disadvantages include:

- A modification to the Fish and Wildlife Service's requests. However, additional exterior bench provided along the eastern border can contribute to meet the request.
- Closer to agricultural land; could increase possibility of crop damages from rising ground water.

5.3.2 Option B

Advantages include:

- Embankment volume is reduced by 10,000 cu. yds.
- Incorporates Fish and Wild life Service's requests; compensates for lost/impacted wetlands by providing 26 acres more than Option A
- Embankment is further away from agricultural land

Disadvantages include:

- Reservoir storage capacity is reduced from optimal by 300 acre-ft.

5.4 West Boundary – Adjacent to Future A-2 Reservoir

See Figures 2 and 4.

The cross-section for this sector of the western border will provide a transition between the sectors identified in 3.3.1 and 3.3.3. This stretch includes a 0.5 mile wide strip west of the original boundary line which will act as a buffer zone between the reservoir and the adjacent agricultural land. Consequently, there are no immediate restrictions for the location of the embankment relative to the outside properly line, and optional configurations are not necessary. The profile in this area would include the embankment, a 100 ft wide bench, and a seepage canal of sufficient width to provide for optional seepage recovery.

5.5 South Boundary and West Boundary Adjacent to STA 3/4 Supply Canal

The perimeter configuration options for the boundary adjacent to the STA 3/4 supply canal are shown on Figure 5.

Option A would be to construct the reservoir embankment against the existing supply canal embankment. In so doing, the existing seepage canal would be filled in. Because the supply canal must remain in operation throughout construction, this option would require a well thought out construction plan to allow filling of the seepage canal will be required.

Option B would be to construct an embankment with a 50 foot bench similar to that shown for the other perimeter profiles.

5.5.1 Option A

Advantages include:

- Reservoir storage capacity maximized. 3,350 acre-ft more than Option B.
- Less stripping of peat required
- Homogenous embankment section simplifies construction
- Seepage canal not required.
- Cutoff wall installation not required.
- Embankment volume is reduced.
- Existing perimeter levee can be used as access road.

Disadvantages include:

- Increased construction difficulty due to the need to maintain operation of supply canal and adjacent seepage canal.
- Unable to inspect downstream slope of embankment since it would always be submerged in the supply canal.
- Possibility of need to control seepage from supply canal to reservoir.
- Construction cost would potentially increase since all embankment material would have to come from the interior footprint of the reservoir.

5.5.2 Option B

Advantages include:

- Embankment volume reduced.
- Simplifies construction.
- Compensates for lost/impacted wetlands by providing 40 more acres than Option A.

Disadvantages include:

- Reservoir storage capacity is reduced by 3,350 acre-ft.

6. CONSIDERATIONS IMPACTING CROSS-SECTION OPTIONS

6.1 Water Depth

Based on the District's design parameters and on an initial evaluation of wave run-up and internal breakwaters, for a water depth of 12 feet, and an embankment with a 3:1 slope, the minimum required embankment height is estimated to be 26 feet above existing grade. Cross-section options were also developed under the assumption that the reservoir would have a water depth of 12 feet. Embankment cross-section options are discussed in the Embankment Technical Memorandum.

Further evaluation of wave run-up conducted to determine the impact of raising the reservoir's water depth to 15 ft., has shown that for every foot in increase in depth, the embankment will have to be raised 1 foot. No additional free board for storm surge and wave run up would be regional To determine the cost effectiveness in increasing the water depth from 12 to 15 feet, the changes in water storage capacity and embankment volume are as follows:

- Approximate reservoir storage capacity increases from 194,500 to 242,500 acre-ft (24%)
- Approximate embankment volume increases from 9,604,500 to 11,837,000 cu. yds. (23.2%). However, the bulk of the volume increase will be for lower cost material (remain fill), and cost increases would be in the range of 10 to 15%.

The above calculations were made assuming embankment cross-section Option A, Figure 3, for all four boundaries.

The optimum depth/volume will require an analysis of not only the embankment costs, but also the seepage impact due to higher water levels, the increased potential for seepage loss, and the cost associated with increased pumping.

6.2 Impact to Background Water Level

Even though the Corps has indicated that the water table rise should be limited to 0.5 feet, it is necessary to determine what is allowable based on the constraints that exist on each boundary. The impact to the background water level will not be known until the results from the MODFLOW groundwater models are obtained.

6.3 Fish and Wild Life Goals

In their Planning Aid Letter, the Fish and Wildlife Service has made the following requests that have an impact in the reservoir's configuration, some of which may alter the configuration of the reservoir:

- A 500-acre wild life habitat buffer zone is to be provided on the northern and western perimeters of the EAA reservoir. It will consist of a short-hydroperiod wetland with an associated upland

- The native habitat and biological diversity for the EAA project reservoir is to be improved, to provide improved ecological stability and resiliency at local, regional, and system-wide scales

7. CORNER CONFIGURATION

Reconfiguring the Reservoir corners has been considered as an option for reducing the cost with minimum/reduction in reservoir volume. The following benefits for rounding the Reservoir corners were identified:

- Reduced volume of embankment (even after embankment height is increased slightly to maintain the same storage in the reservoir)
- Decreases length of the cutoff wall
- Reduces length of horizontal drainage blanket and chimney drain (if one is used). Both these items are expensive components of the embankment
- The area between curves and property line becomes available for additional wetland, parking areas, and possibly small borrow areas for construction or contractor staging areas
- Reduces length of embankment under which seepage can occur
- Reduces length of seepage collection canals
- Less road surfacing required
- Less downstream erosion protection
- Disadvantage that seepage will increase

7.1 Impact of Circular Corners on Parcel A-1 Reservoir

To compare both corner configurations, a 4,000 ft. radius was selected (See Figure 6). Each of the four corners of reservoir A-1 was analyzed independently in order to measure their individual impact on embankment volume and water storage capacity. The results are as follows:

7.1.1 Northeast Corner

- Reduction in acre-feet of water stored: 170 acre-ft
- Reduction in embankment volume: 19,900 cubic yards

7.1.2 Northwest Corner

- Reduction in acre-feet of water stored: 850 acre-ft
- Reduction in embankment volume: 123,500 cubic yards

7.1.3 Southwest Corner

- Reduction in acre-feet of water stored: 850 acre-ft
- Reduction in embankment volume: 123,750 cubic yards

7.1.4 Southeast Corner

- Reduction in acre-feet of water stored: 3,350 acre-ft
- Reduction in embankment volume: 513,000 cubic yards

Several additional factors affect the feasibility of circular corners. The location of the new Northeast Pump Station and access to its expected location limit the use of circular corners in the northeast. Construction of the embankment above the seepage canal along the STA Supply Canal would limit the geometry of the reservoir embankment configuration in the southwest corner, and would limit the use of circular corners here as well. However, the use of circular corners in the southeast corner of the reservoir has additional benefits other than cost savings as discussed in the Reservoir Configuration TM II under Work Order 7. One such benefit pertains to existing helipads; a circular corner in the southeast prevents the relocation of the existing helipads. Additionally, a circular southeast corner would aid in the configuration of a control structure allowing flow from the reservoir into the G-370 suction canal. Therefore, if circular corners are applied only in the northwest and southeast corners, the reservoir achieves a total storage over its requirement of 190,000 acre-ft with both cost, performance, and construction benefits.

7.2 Impact of Circular Corners on Reservoir A-1

The overall impact on embankment volume by introducing circular corners with a 4,000 ft radius are as follows (See Figure 7):

Square Configuration

Embankment Volume: 10,270,000 cu yd.
Volume of water stored: 191,300 acre-ft

Circular Configuration

Embankment Volume: 9,910,000 cu yd.
Volume of water stored: 190,600 acre-ft

Circular Configuration vs. Square Configuration

Embankment Volume: Decreases 360,000 cu. yd. (3.5% reduction)
Volume of water stored: Decreases 700 acre-ft (0.037%) (Same approximate volume of water stored in both configurations)

8. CONCLUSIONS

This memorandum summarizes the work conducted to develop the reservoir configuration for the EAA Reservoir A-1. Included is a discussion of the different configurations resulting from requests and constraints found at each one of the boundaries. It is important to note that continued seepage analysis will help define the final configuration or configurations of embankments, depending on the particularities and requirements of each boundary. Based on the Seepage Control Technical Memorandum, the following will be required prior determination of the reservoir's configuration:

8.1 East boundary Configuration

As the DOT no longer requires additional setback, the east boundary should have a total setback of 260 feet to accommodate construction of the embankment, construction of the seepage canal, provide long term embankment inspection, and provide additional area to contribute to the Fish & Wildlife Department's requests.

8.2 North Boundary Configuration (and West boundary north of A-2 Reservoir)

The existing palm trees should not be a driving factor in determining the reservoir's configuration along the north boundary. Even though the Fish and Wildlife Service's requests do not have a major impact in the EAA Reservoir A-1's water storage capacity, they will have a considerable impact once the A-2 reservoir is added, considering that these requests will also apply to reservoir's A-2 north and west boundary. The total wetland area affected by the construction of the A-1 and A-2 reservoirs is estimated at 600 acres. If the Service's objective is to compensate for the impacted or lost wetlands as a result of constructing both reservoirs, this can be accomplished by designating the protruding northwest corner of reservoir A-2 as such, for a estimated total of 550 acres. Due to the amount of embankment required to enclose this panel, the cost per acre foot for reservoir in this area will be disproportionately high anyway.

8.3 West Boundary Configuration (Adjacent to Agricultural Land)

There are no immediate restrictions in this area

8.4 South Boundary Configuration Adjacent to STA 3/4 Supply Canal

Two alternative reservoir alignments are possible along the existing STA 3/4. One alignment eliminates the seepage collection canal for the STA 3/4 supply canal by laying the Reservoir A-1 embankment up against the STA canal levee, if there are no stability issues. The other reservoir alignment provides a buffer area between the Reservoir A-1 embankment and the existing seepage canal. Modeling should be performed during the BODR to evaluate the effect of both of these alternatives on the STA 3/4.

8.5 Reservoir Embankment Corner Configuration

The advantages and possible economic savings of having circular embankment corners represent a design retirement and should be further analyzed during the BODR.

9. REFERENCES

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Specifications for Caterpillar 740 Articulated Dump Truck from Caterpillar web site. http://www.cat.com/cda/layout?m=37840&x=7&location=drop

Figure 1 Parcel A Site Plan

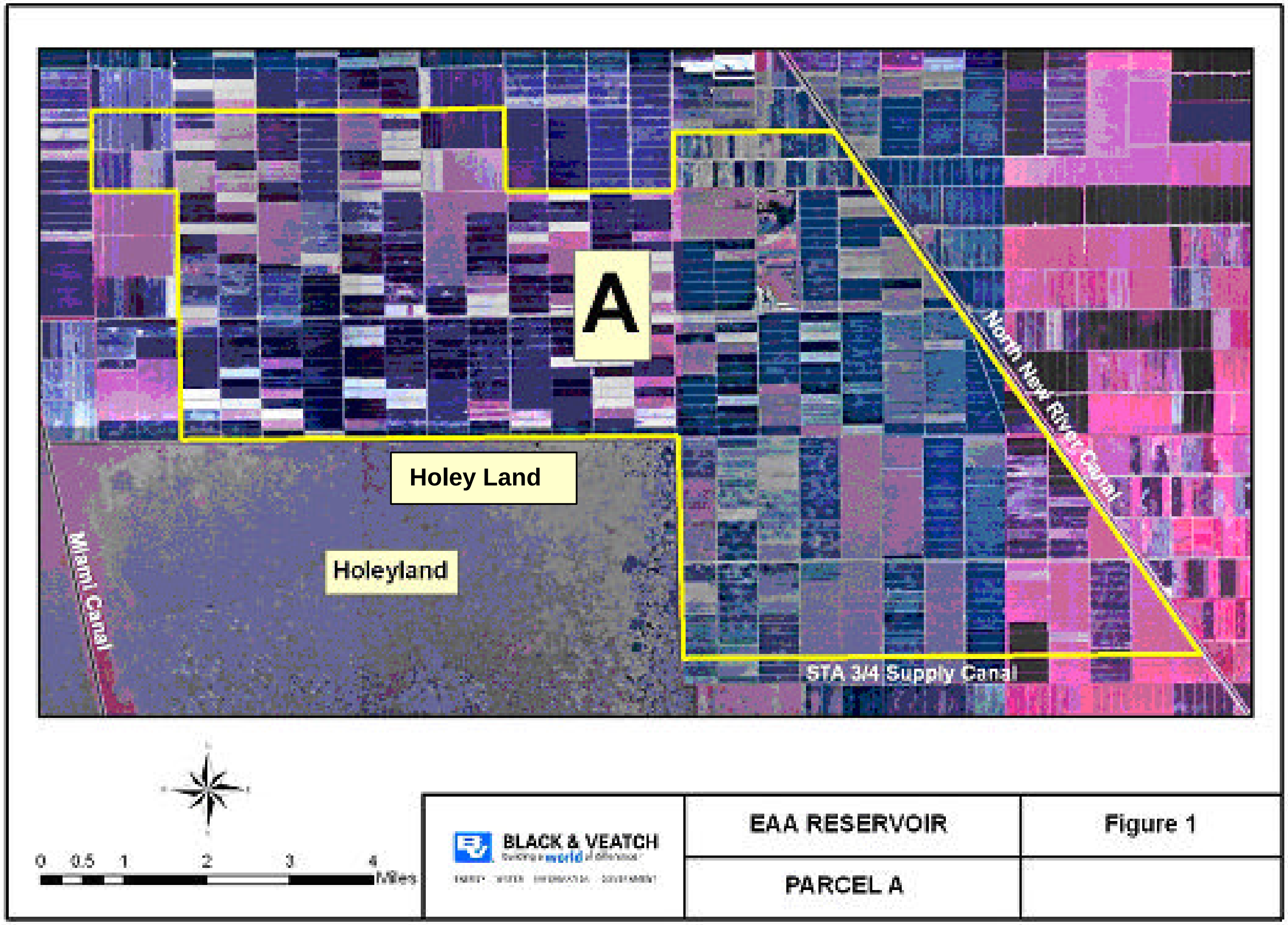

Figure 2 Parcels A-1 and A-2 Site Plan

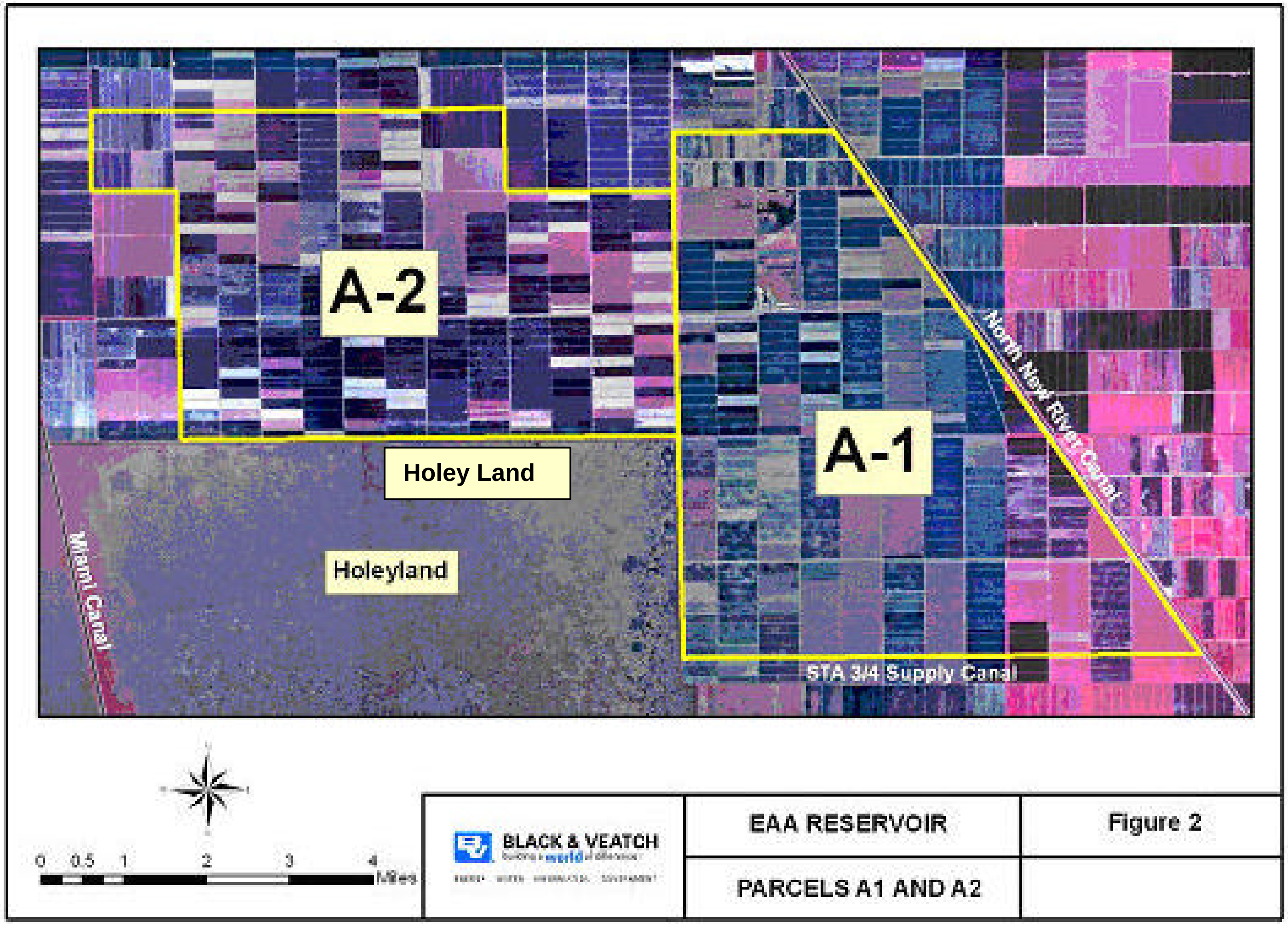

Figure 3 Perimeter Configuration Options for the East Boundary

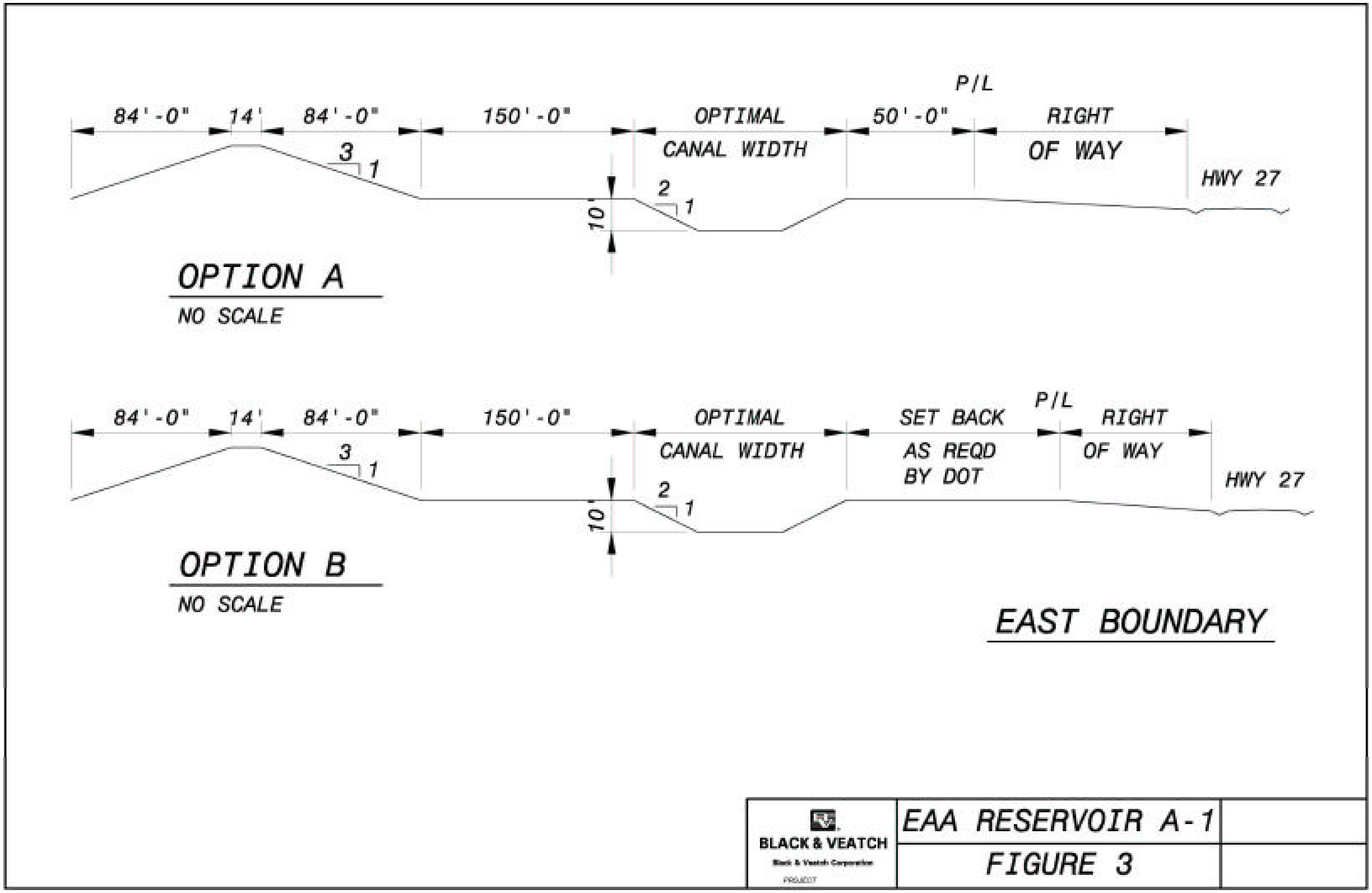

Figure 4 Perimeter Configuration Options for the North Boundary

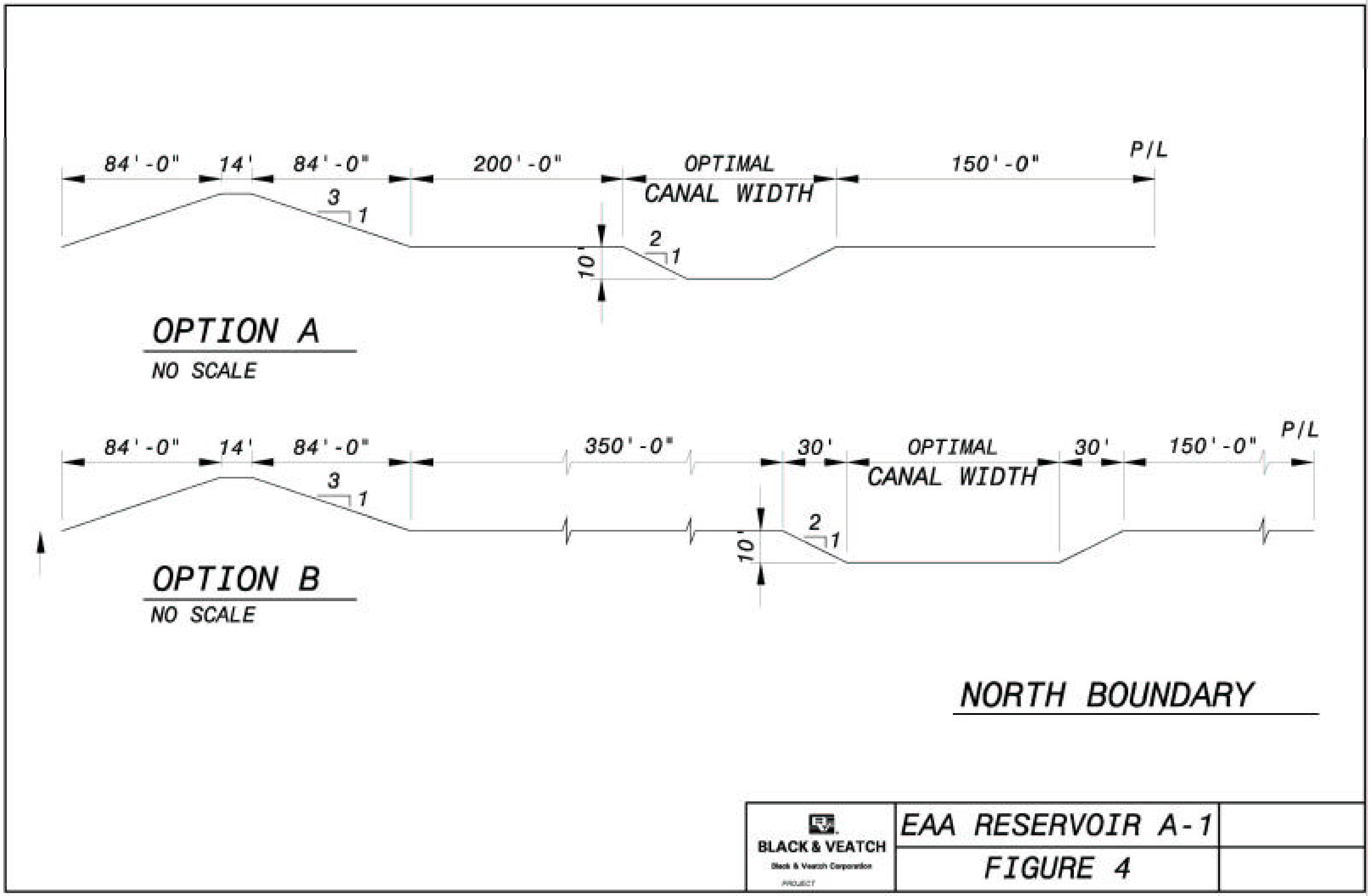

Figure 5 Boundary Adjacent to STA 3/4 Supply Canal

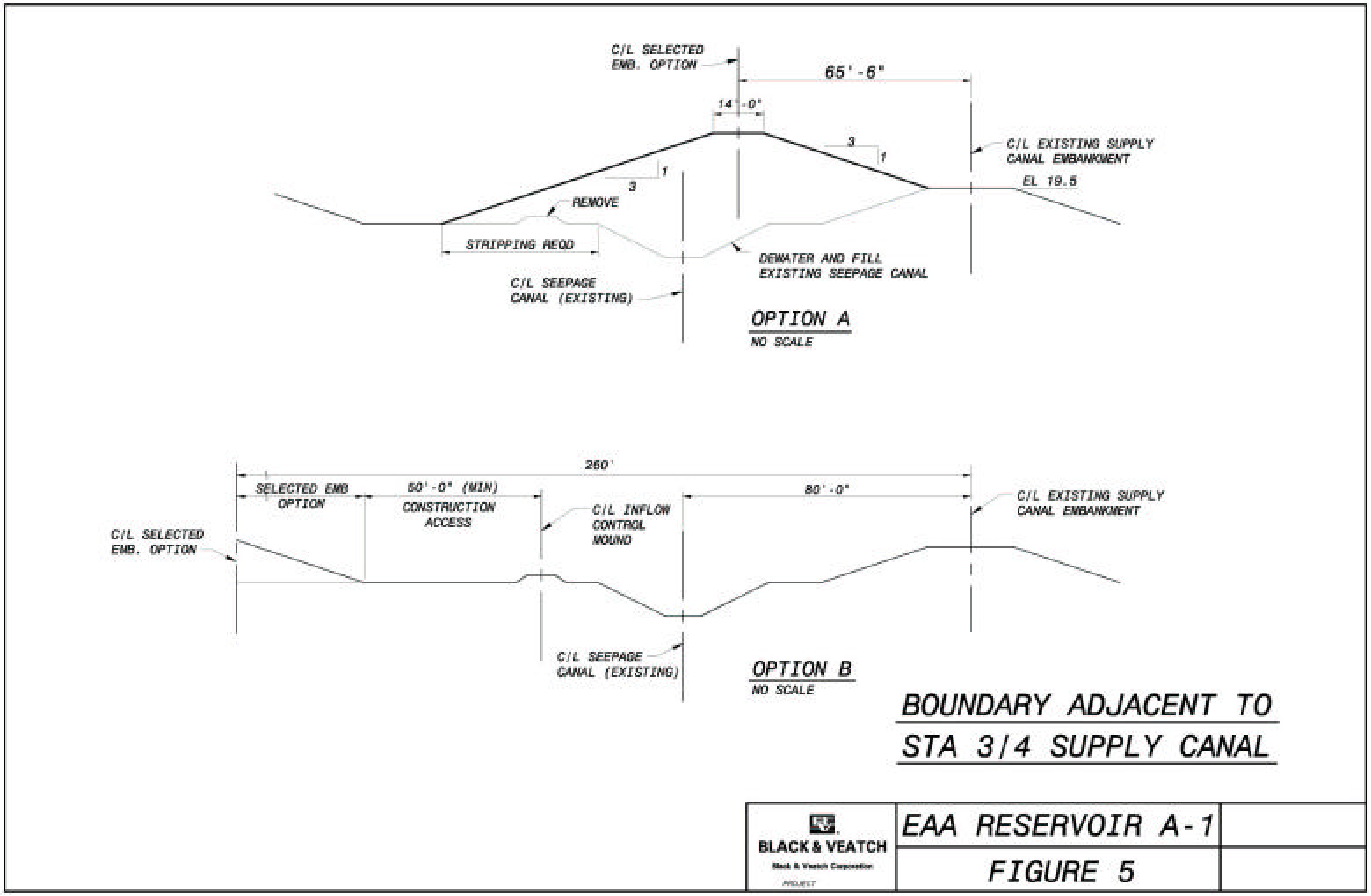

Figure 6 Embankments Parcel A-1

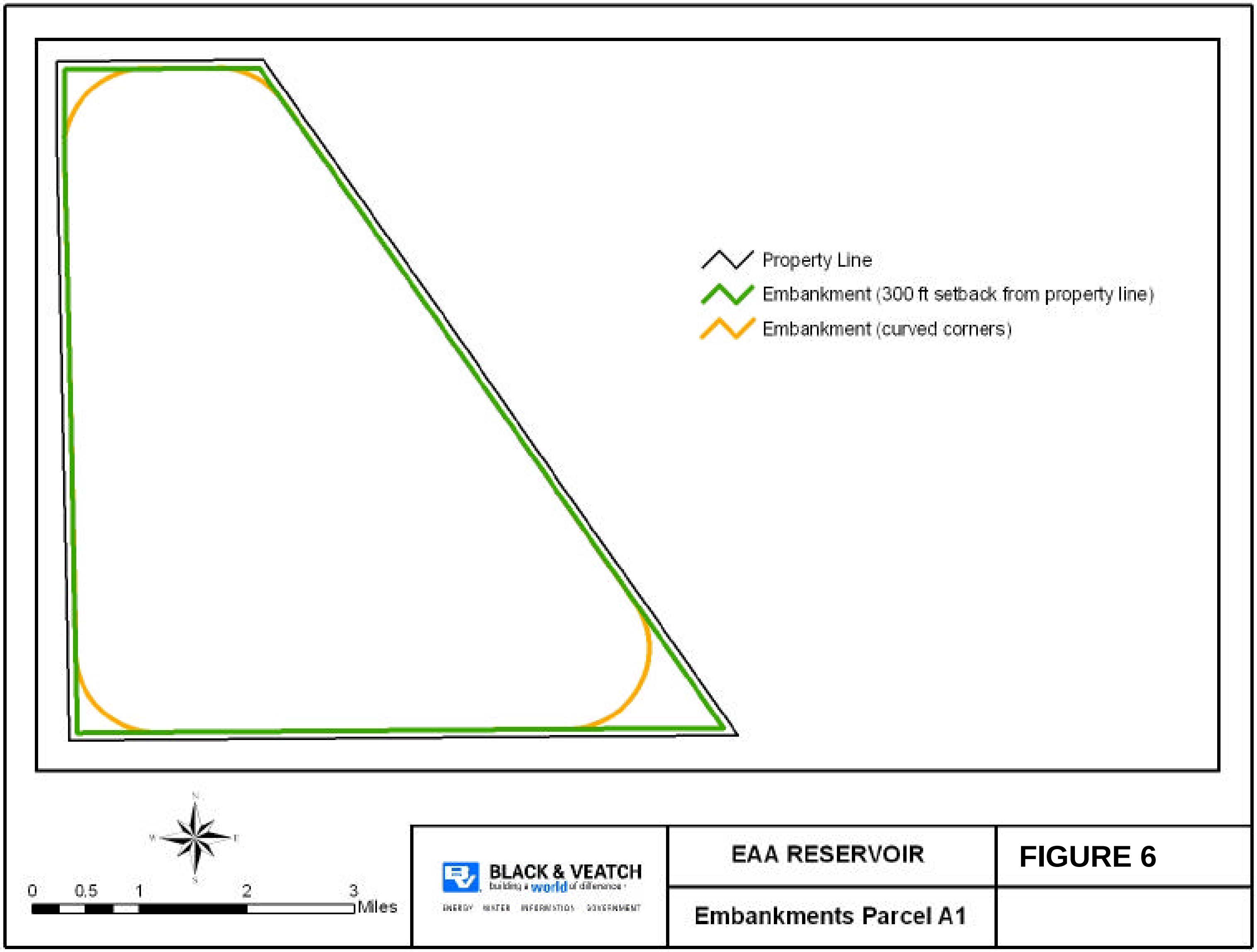

Figure 7 Embankments Parcel A